Machinery Health Monitoring Through Low Cost Maintenance Tribology Techniques

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Abstract

In general, for Small and Medium Enterprises (SMEs), finance for “High-Tech” Condition Monitoring (CM) equipment is extremely difficult. In term of financial constraint, it is virtually impossible to furnish maintenance personals with such a thing. In this particular paper, however, the more “Low-Tech” approaches of Machinery Health Monitoring (MHM) for lubricated machinery in particular, is proposed. In short, these techniques are quite simple and also low cost but proof to be useful in several applications particularly for the SMEs sectors.

Keywords : Machinery Health Monitoring, Maintenance Tribology

1. Introduction

In condition monitoring of machinery, in general, the “High-Tech” and high cost equipment is normally employed i.e. vibration meter, thermography, used oil analysis apparatus. However, in some places of the world, it is hardly be a good practice to invest for such a thing. On the other hand, a big burden of “breakdown maintenance cost” is also an industrial bust to conquer. Hence, the need for low cost condition monitoring technique is inadequate. Generally, In an oil-lubricated machinery, three basic ways in performing used oil analysis are evidences: Filter Debris Analysis (FDA), Used oil/grease analysis and Magnetic Chip Detector (MCD) ferrous wear particle analysis. Majority of tribosystem failure starts from a cheap component primary failure and lead to a more severe failure i.e. secondary failure of a system or catastrophic failure in a worst case.

2. Used Grease Debris Analysis

Due to normal wear and friction, it is not uncommon to find small amounts of debris in used grease samples. An excessive amount of debris in used grease samples can indicate possible failure. In addition, wear debris morphology can be used to identify wear mode/mechanism that generated them. Generally, detectable failures are those caused by component wear and gradual accumulation of contaminants such as dirt, dust, debris and moisture. By analyzing wear particles and contaminants in the used grease samples, problems may be identified early, before catastrophic bearing failure occurs [1-2].

2.1 Wear Debris Analysis of Used Grease from Simulative Four-Ball Sliding Wear Tester

A series of tests was undertaken using a conventional four-ball machine. In simple sliding mode, the wear debris characteristics before and after scuffing were determined in term of their morphological aspects. Tests were conducted as related to standard test preparation and procedure – IP 239/85 (1992). At the end of each successive test run, used grease was carefully collected on labeled glass slides and grease sample bottles. Wear debris

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Fig. 1 Mild sliding wear debris

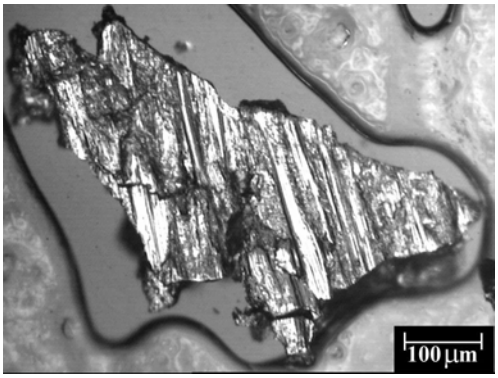


Fig. 2. Severe sliding wear debris

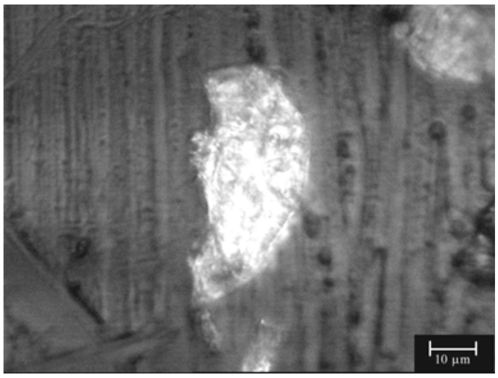


Fig. 3 Before pitting wear debris

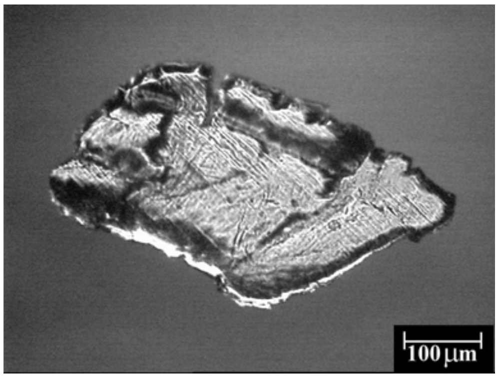


Fig. 4 After pitting wear debris

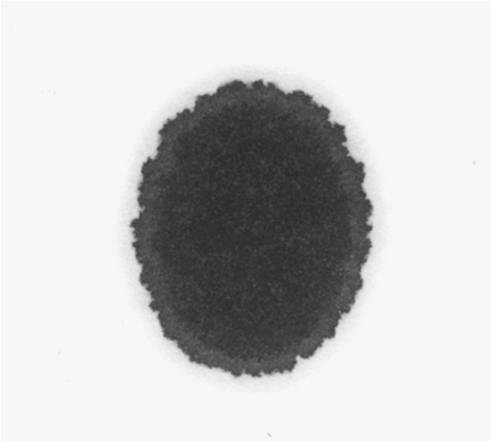
from each test was inspected qualitatively and photomicrographs of representing wear debris in each wear regimes were taken. Figs. 1 and 2 illustrate typical wear debris characteristic found in mild and severe sliding wear mode respectively.

2.2 Wear Debris Analysis of Used Grease from Simulative Four-Ball Rolling Wear Tester

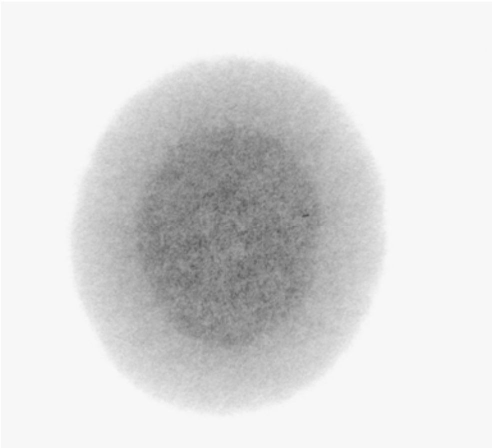
In this aspect, using the same four-ball machine, rolling contact pitting fatigue tests were carried out. Tests were performed as per standard test preparation and procedure – IP 300/82 (1987). Some of the rolling wear tests were stopped prior to pitting failure of the top ball so that representative "pre-failure" wear debris can be collected for comparison with those from "after pitting failure".Upon completion of each test, the used grease sample was collected and subsequently analyzed under an optical microscope. Figs. 3 and 4 represent typical wear particles from "before" and "after" pitting of the top ball.

3. Blotter Paper Test

This newly developed technique (being in a process to apply for U.S. patent) is a quick and simple test used to estimate the general condition of lubricant. It involves placing one or two drops of used engine oil on an inclined blotter paper (either 240M grade or Whatman No. 4 filter paper). The oil drops spread out and dry, the large particles remain within a center corona. Further dispersion leads to oil penetration and filtration through the paper. A sharply defined corona around the oil-wetted area indicates the present of sludge. A good degree of correlation is found between a conventional blotter test method and an inclined planar chromatography method as shown in Figs. 5 and 6 respectively [3-4].

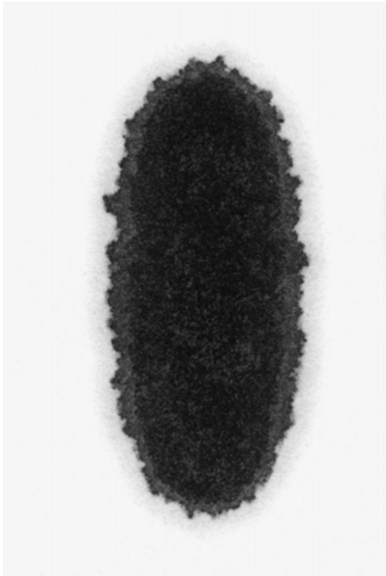


(a) Poor dispersancy

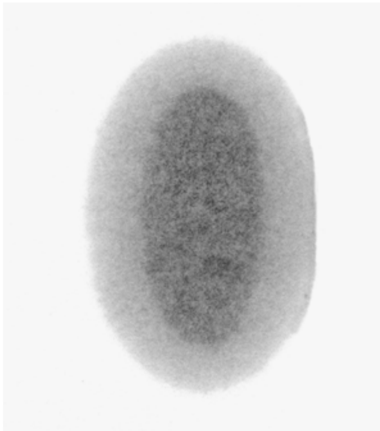


(b) Good dispersancy

Fig. 5 Typical result of an oil spot test (conventional method)



(a) Poor dispersancy



(b) Good dispersancy

Fig. 6 Typical result of an oil spot test (new method)

4. Filter Debris Analysis (FDA)

As it has long been recognized that wear debris and contaminant trapped by oil filter are invaluable to condition monitoring analysts. Filters of lube oil of earth moving vehicles were collected and consequently contaminants and wear debris were extracted and assessed visually under conventional microscope and, in some cases, scanning electron microscope (SEM). Two sets of oil filters from different engine operating modes, namely, run-in and overhaul period, were assessed to demonstrate the distinction between debris characteristics. The filters to be analyzed are cut by a special tool to prevent additional metallic particles from its housing. Debris is separated from the oil filter media by submerging the oil filter in proprietary solvent and applying ultrasonic cleaning for 15 minutes. The debris is then captured on a 0.4 μm absolute, polycarbonate Millipore filter using a vacuum to expedite the filtration process. Figs. 7 and 8 show typical debris characteristic found on the Millipore filters. Elongated wear particles are generally found in the filter collected from run-in period. On the other hand, chunky and/or spherical type wear particles are normally presented in those collected from overhaul period [5].

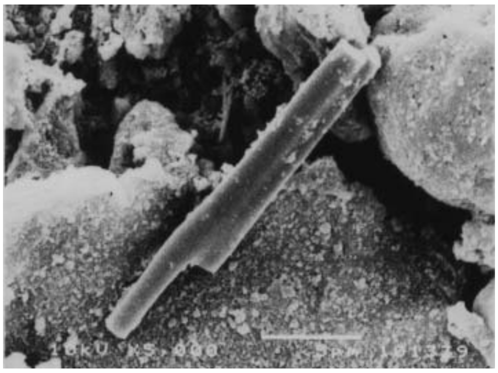


Fig. 7 Elongated wear particle

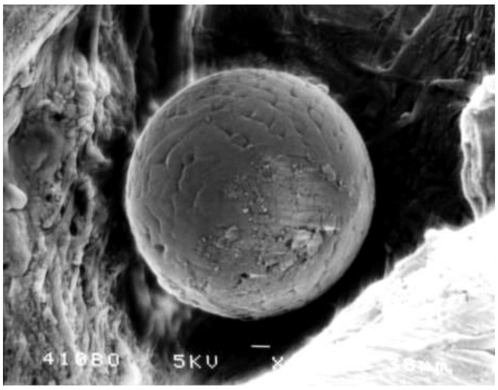


Fig. 8 Spherical wear particle

Fig. 9 Condition of a MCD located in the final drive after 10,000 km

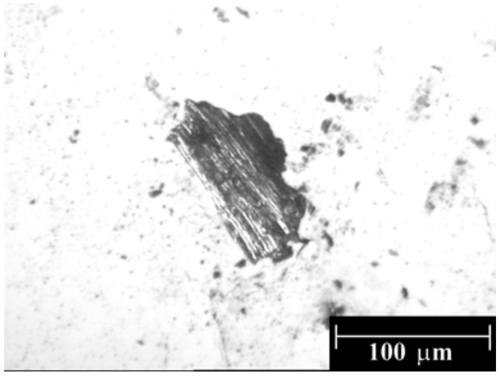


Fig. 10 Combined rolling and sliding wear particle

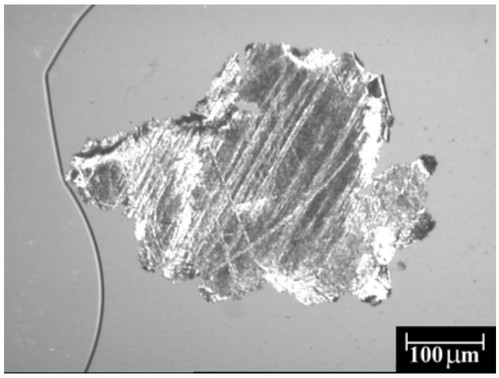


Fig. 11 Severe sliding wear particle

5. Magnetic Chip Detector (MCD)

In power transmission such as gearboxes, engine crankcases or final drives, failure of one part will cause a chain reaction of secondary failure. If “impending failure” can be identified at an early stage, then suitable preventive measures can be planned in advance. This identification is the objective of the MCD through ferrous wear debris monitoring at strategic positions in the lubrication system. Typical MCD and ferrous wear particles from passenger car are shown in Figs. 9 to 11 [3-4].

6. Conclusion

The low cost used oil and wear debris analysis program that has been implemented for industrial application has proven to be useful diagnostic tool for condition monitoring. It is able to distinguish between normal wear of internal components and potentially damaging abnormal wear situations and, in the case of abnormal wear, is able to identify possible wearing components. The low cost technique has been found to be correlate with other condition monitoring techniques already in use and, in many instances, has been the determinant of whether a system is to be returned for overhaul.

7. Acknowledgements

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